Robustness of Large Networks

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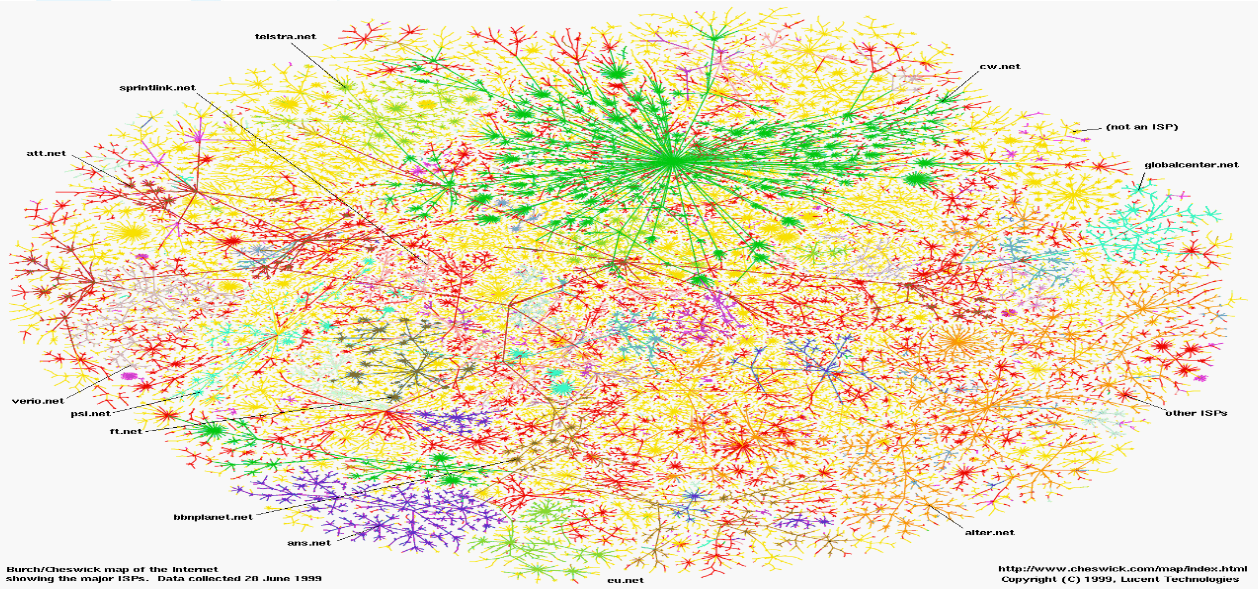

Burch/Cheswick map of the Internet
showing the major ISPs. Data collected 28 June 1999

http://www.cheswick.com/map/index.html
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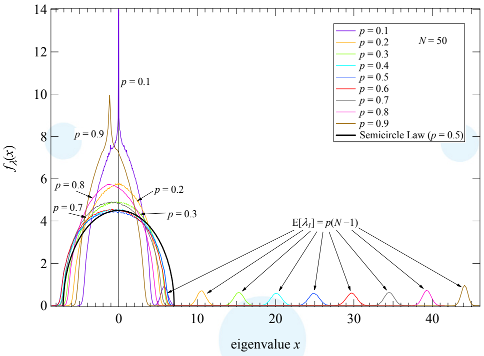
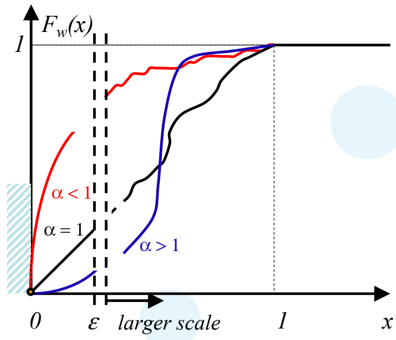
What is robustness?

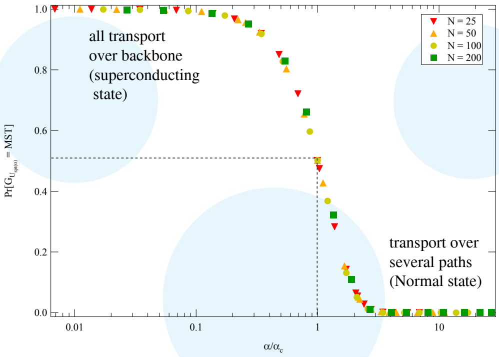
Robustness quantifies the level of protection of large networks against failures, viruses and other attacks. How can we measure robustness? What are the relevant metrics? How to make a network robust?
Novelty: we combine information obtained from two different domains: (a) topology domain (adjacency matrix) and (b) spectral domain (eigenvalues). Inspired by signal processing, some properties of a graph are better controlled or easier understood in the topology domain and vice versa.

Is there a universal theory of robustness for all valuable large infrastructures such as the Internet, power grids, road networks, etc.?
It is known that the spectrum in large random graphs is described by Wigner's semi-circle law. Is there a scaling law for other types of large infrastructures? What does the spectrum teach us? How can we use it to improve the robustness of a network?



What is the influence of link weights on the transport in a network?





Link weights specify the importance of a link in the network. Transport mainly follows "shortest paths". The shortest path is dominated by the smallest link weights w in an ε region around zero. Any link weight distribution around zero is of the general type $F_w(x) \sim c.\ x^\alpha$ where α is called the extreme value index of the link weight distribution.
When α = 1, the link weight distribution is regular.
When α > 1, the effect of the link weight distribution on the shortest path with respect to the underlying topology decreases.
When α → 0, we enter the "strong disorder limit" with heavily varying link weights

The phase transition in the union $G_{U\ spt(\alpha)}$ of shortest paths (i.e. the observable part of a network) seems nearly universal for all graphs: the critical α_c scales as $\alpha_c = O(N^{-\beta})$ where $\beta \approx 0.62$. This "link weight" phase transition follows a power law β which is often observed in nature. If the link weights can be chosen independently of the underlying graph, transport can be switched over two entirely different set of paths. Above α_c, normal transport is obtained which is spread over many links in the network, whereas below α_c, all transport uses the minimum spanning tree. Switching between load-balanced (normal state) and between back-bone routing (superconducting state) is possible by tuning the extreme value index α.

NAS projects on Network Robustness

NWO/Glance: Robunet
Bsik NGI: Understanding Complex Networks

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